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ABSTRACT

In the late 1960s and early 1970s a considerable amount of research was conducted on methods for authoring and structuring instructional materials by researchers who did not, at that time, have access to the existing delivery systems necessary to fully implement their ideas. One of these methodologies is Structural Communications, developed by Anthony Hodgson and his associates in the United Kingdom. This authoring methodology was implemented in a paper-based format with great success, but it seems that its potential for computer-based instruction, its true original purpose, has never been fully exploited. This paper outlines the characteristics of this approach and describes the authors' work at Syracuse University over the past two years which applies the principles to interactive video simulations. (33 references) (Author)

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INTERACTIVE VIDEO AND COGNITIVE STRUCTURES: A TECHNIQUE FOR ENHANCING THE EFFECTIVENESS OF INTERACTIVE SIMULATIONS AND GAMES

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ABSTRACT

In the late 1960's and early 1970's a considerable amount of research was conducted on methods for authoring and structuring instructional materials by researchers who did not, at that time, have access to the existing delivery systems necessary to fully implement their ideas. One of these methodologies is Structural Communications, developed by Anthony Hodgson and his associates in the United Kingdom. This authoring methodology was implemented in a paper-based format with great success, but it seems that its potential for computer-based instruction, its true original purpose, has never been fully exploited. This paper outlines the characteristics of this approach and describes our work over the past two years which applies the principles to interactive video simulations.

1.0 CONTEXT

1.1 SIMULATIONS AS EDUCATIONAL EXPERIENCES

Simulations have been categorized into many different types (Percival & Ellington, 1980, Dean & Whitlock, 1983, Romiszowski, 1984). Basically, educational simulations are representations of reality which allow the student to explore various actions and experience the consequences of those actions in a simulated environment. When designing simulations for use with advanced technologies, as with other media, the same guidelines for effective instruction should be followed. Many researchers have identified primary features of simulations (Alessi and Trollip,

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1985, Hannafin, 1988) which follow those guidelines. Although different terms are used, those features essentially include some type of orientation/directions, the presentation of a scenario, a problem set, or a set of events, (depending on the type of simulation), followed by possible student actions with a range of plausible system reactions/consequences to student responses and finally, a concluding section with some mechanism for qualitative summary feedback on their performance--in essence, a debriefing session.

While many CBI and CBIV simulations set up the scenario and create an exciting simulated environment with appropriate system responses, few create an effective "dialogue" with the learner to analyze and bring to consciousness essential concepts, principles and rules used in the simulations. Most of the feedback is composed of summative, qualitative statements analyzing the learner's responses in a "book-like" fashion. It does not guarantee that the learner reflects on the reasons why certain decision strategies may be better than others.

Hannafin (1988) describes CAI simulations as effective for capitalizing on the "'thinking' and evaluative capabilities of the computer better than other designs". We like to think about CAI and CBIV simulations incorporating some form of debriefing as effective for capitalizing on the "thinking" and evaluative capabilities of the <u>learner</u>. Higher order learning may be enhanced most dramatically through the power of the computer during the debriefing session. Sia and Sydnor (1987) define debriefing in role playing as that which "involves the student's own reconstruction of prior learning experiences. The teacher asks the students to express in their own words what they have learned after a lesson unit or course. This alternative puts on the students the ability to take responsibility for organizing, retaining and making sense of what they are exposed to in classes" (p. 8). Boud, Keogh and Walker (1985) stress the importance of "reflection" as the principal means of "turning experience into learning." They see all experiential learning as a cycle of three stages: "preparation, engagement in an activity, and the processing of what has been experienced." The third discussion or debriefing stage is critical to the achievement of higher order cognitive objectives.

Providing opportunities for this type of debriefing is especially vital for decision making simulations (Romiszowski, 1986). In these simulations, often there are no absolute right or wrong answers, and so it is the mental processes which are used to make decisions which are important to debrief. To address this challenge, we felt that Anthony Hodgson's Structural Communication offered great potential as a debriefing strategy

for simulations. We tested out this assumption with a paper-based version and, more currently, with a computer-based version of a de-briefing tutorial, designed to enhance an existing CBIV simulation game.

1.2 BACKGROUND TO THE STUDY

DECISION POINT is an interactive video simulation which puts the learner in the position of "Vice President of Sales" of a high tech manufacturer. As the producers, Digital Equipment Corporation, describe it, it is a "Living Case Study": a situational simulation in which the student interacts with dramatized scenarios representing occurrences in the company, interviews key personnel and makes decisions on a total of ten issues that reflect on the success of the sales effort (Digital Educational Services, 1985).

There are also several simulations-within-the-simulation. Often the student may call up an interactive spreadsheet, or other decision support software, which allows experimentation with the relationships between certain policy decisions and the effect on the company's sales.

The students have to make all ten key decisions, though they may put those decisions on hold temporarily to await more information. Delayed feedback on the effect of the decisions on sales is given in a realistic manner, but no corrective feedback is available, nor are the general principles applied (or mis-applied) by the student discussed in a manner more than simply presenting the effectiveness or ineffectiveness of the decision contributing to sales increases. As it stands now, DECISION POINT typifies simulations with no interactive debriefing strategies. "The manual suggests that "...from this kind of experience - from living through the case several times - you will learn about the complex interrelationships of causes and effects in managerial decision making...by taking the course again and again you will be able to develop the feel for business that often characterizes top executives" (Digital Education Services, 1985).

Alessi and Trollip (1985) note three advantages of simulations: motivation, transfer, and efficiency. While we have found that DECISION POINT is very motivating, we questioned the efficiency of repeating this two-hours-or-so-a-time exercise to develop the feel for business. Also, we had out doubts concerning the amount of transfer-of-learning that would occur to other managerial decision making contexts.

1.3 INITIAL OBSERVATIONS

When DECISION POINT was first tested by students and staff at Syracuse University, records were kept of the results achieved on successive repeat attempts. It was found that, typically, students would register a marked improvement from the first to the second attempt, but then the learning curve would flatten out, with little further improvement on the third and fourth attempts. The level at which this plateau would occur varied. A few students achieved close to maximum possible sales on the second execution, leaving little room for further improvement, but many would flatten out well below the goals set for them by the simulation. Follow up discussions showed that one difference between the high and low achievers was the extent to which they REFLECTED on the general principles which were involved in the scenarios that were presented to them by the interactive video simulation. It would seem that some form of debriefing to encourage "deep processing" of the general theoretical principles of management behind the practical decisions would enhance the instructional effectiveness of the package.

When "subject matter experts" (practicing marketing/sales managers and professors of management) participated in the experience, their first-run sales performance often reflected disagreement with the theoretical premises on which the decision model of the simulation was based. They would make a "wrong" decision and, on being informed that they were wrong, would engage in discussions on the probable model embedded in the game and other alternative theoretical positions that could, in their opinion, be validly adopted. Often, these "SME"s disagreed with each other as well as with the simulation and these discussions led us to many insights on the complex conceptual structures underlying management decision making. The students of management would benefit greatly from an opportunity to examine these cognitive structures used by experts.

These observations led to the design of a "debriefing tutorial" which would allow students to reflect on the cognitive structure that they had applied to a given problem and compare it with the cognitive structures of expert managers. The methodology for the design, development, and delivery of this debriefing session is based on "Structural Communication."

This debriefing tutorial allows each student to examine his or her own cognitive structure and compare it to that of the authors of DECISION POINT and also to other viewpoints that may be validly defended. Initial pilot studies, using a paper-based version, (Romiszowski & Grabowski, 1987, Romiszowski, Grabowski, & Damodaran, 1988) showed a marked improvement in the learning and application of the general management principles involved,

when the CBIV simulation-game was followed by the tutorial. A computer-based version has now been produced and is under formative evaluation (Romiszowski, Grabowski & Pusch, 1988). In the present paper, we focus on the principles of "Structural Communication" and their application to the development of in-depth tutorials that explore and compare the cognitive structures of students and experts in a given domain.

2.0 STRUCTURAL COMMUNICATION

2.1 ORIGINS

The structural communication methodology created by Anthony Hodgson (1968, 1972, 1974) applied the principles of cognitive psychology to the, then, behaviorist-oriented programmed learning movement. This methodology is perhaps one of the most powerful ways of structuring automated, conversational dialogues to achieve higher-order learning objectives, yet to have been invented. It is based on the practical application of cognitive learning principles to self instruction (Hodgson, 1974), and has proved itself in many varied educational contexts (Egan, 1976; Romiszowski, 1976, 1986) including high level management decision making (Hodgson and Dill, 1970; Hodgson, 1971). For a variety of reasons, it is little, if ever, used by the current generation of Computer-Assisted-Learning materials developers, but holds great untapped potential for improving current interactive instructional systems design (Romiszowski and Grabowski, 1987, Romiszowski, Grabowski, and Damodaran, 1988).

2.2 KEY FEATURES

In order to promote reflective thinking it is postulated that one must present stimulating initial learning materials followed by a dialogue which will provide challenges to the learner to solve new and multifaceted problems. This dialogue must be highly personalized and interactive. The structure which Hodgson used included several key features. These features include:

* initial learning materials,
* problem sets,
* random array of response components in a response matrix,
* discussion guides and discussion comments which are linked to the inclusion or exclusion of items in the response sets.

This guided dialogue was simulated in printed texts which, after presenting a basic reading assignment, would pose a number of open ended discussion problems. However, in order to respond, the reader, rather than structuring and writing an essay, would

construct a sort of essay outline by selecting the factors that make up the "best case" or solution from a long list of usually between 20 and 30 candidate statements (Hodgson, 1968, 1971, 1974).

The learner must analyze the information presented, synthesize a personal viewpoint and select the items from the response matrix which support this viewpoint. The structural communication methodology handles the dialogue by means of a diagnostic tool called a discussion guide. The discussion guide then identifies specific comments that the author has written to clear up certain misconceptions or compare contrasting viewpoints.

2.3 AN EXAMPLE

As an example of the approach, we shall analyze one section of DECISION POINT and the associated debriefing tutorial.

In one section of the CBIV simulation, the student must make a decision with respect to the TECHNICAL SUPPORT that the sales force requires. The alternatives are as follows:

a) Leave things as they are. (That is, calling on the help of engineers from the production department to give technical support to sales staff if and when required--a procedure which disrupts the work of the production department), or

b) Make one of the following changes:
   1. train all sales representatives technically;
   2. create a separate support group within sales;
   3. recruit product engineers to be sales representatives,
   4. provide more technical marketing materials for customers.

The original simulation favors alternative 'b2' and rewards this choice by delayed positive feedback, but never engages in a discussion of <u>why</u> that choice may be better than some other, let alone exploring the possibilities of combining several of the alternatives into a multi- faceted decision. The current version of our debriefing tutorial supplied such a discussion by asking the student the following problem question:

> "Which of the principles on the response matrix do you think lend support to the correct decision on solving the technical support problem."

A problem set was composed of ten questions of the type "which principles of good management do you think support the correct decision with respect to ..." followed by one or another of the decision points with which the student was faced during the simulation (e.g., the "Promotion of Harriet Dorfman," "Report Distribution," or "Commission Policy").

Next, the student responds by selecting all relevant "response components" from a response matrix of key phrases that sum all aspects of the topic under study, both relevant and irrelevant to the problem under consideration. This is organized in the form of a table. See Figure 1 for the response matrix developed for the present study and used as a source of response components for all ten decision points.)

[Insert Figure 1.]

Following this, the expert's rules for the analysis and treatment (discussion guide) of a given student's response were involved. Typically, the student may <u>include</u> response components deemed unjustified, debatable, or representing but one of several viewpoints, or alternatively, may <u>omit</u> some component(s) deemed essential, or worthy of debate. Figure 2 shows how the response to the TECHNICAL SUPPORT problem posed in the DECISION POINT debriefing tutorial was analyzed and the feedback treatment defined as a set of logical "if-then" rules).

[Insert Figure 2 here.]

The response analysis/ discussion guide identifies a set of comment statements or "feedback" statements that are appropriate for every significant discrepancy between the student's cognitive structure (as revealed by the response-component pattern) and that of the experts used in developing the debriefing tutorial. These comments are then studied in depth by the student.

Thus, a student is faced with a challenging, rather open-ended problem and responds by constructing a personal multi-component response. This response is analyzed by means of small "logic" program specially developed for this problem and based on the analysis of how experts tend to deal with similar problems. This logic program generates an individualized feedback message composed of perhaps several comments and further presentations, selected from a more extensive set of comments, designed to cover

all commonly occurring differences between viewpoints and approaches to the problem. This approach deals equally well with errors or misconceptions and with alternative defensible viewpoints or theoretical positions.

2.4 DEVELOPING STRUCTURAL COMMUNICATION UNITS

In practice, the "response matrix" shown in Figure 1, the logical analysis of significant "comment-worthy" differences in students' and experts' conceptual structures (Figure 2), and the specific comments were developed through a process of interviewing of experts both during and after the DECISION POINT experience (a form of knowledge engineering). This generated an initial version of the unit. This unit was further refined by experimental use on successive management undergraduate students from the School of Management over a period of two semesters. This experimental use simulated a future fully automated CAI debriefing tutorial with all problems, responses, and comments being presented in a standardized format, in writing, one "screen" at a time but on paper. The "logic program" analyzing a student's conceptual structure was "executed" by the experimenters, using a printed job aid. However, extra, non-programmed student responses or queries, together with resultant experimenter comments were encouraged and recorded as potential input to the refinement of the tutorial.

The current problem-set, response matrix, analysis and discussion guides, and resultant discussion comments are the result of several iterations of this process. Track is kept of the "communal" cognitive structure with respect to the domain of management decision making under study, by means of a matrix of problems investigated crossed with the management principles that may be in play (Figure 3).

[Insert Figure 3 here.]

In effect, one axis of this matrix represents the knowledge base of potentially relevant management principles and the other represents the universe of potential managerial decision-making situations which may call for the use of certain parts of the knowledge base. Each cell on this matrix represents an aspect of the cognitive structure of our "experts." An "E" indicates that a certain principle/concept is "Essential" when dealing with a certain category of decision making. An "S" identifies "Supporting" or "Secondary" considerations. Blank cells represent the expert's views regarding principles that are irrelevant to a given type of decision. Finally a "C" indicates "Conflicting" or "Converse" relationships. These cells draw our

attention to aspects which often appear to be of relevance or importance to the novice, but in the expert's opinion, should be ignored or interpreted otherwise. The inclusion of an "E" relationship indicates agreement with the expert's "mainstream" viewpoint and may warrant little (other than confirmative) comment. The omission of an "E" relationship, however, almost invariable calls on a comment that invites students to reflect on the implication of this aspect of their response. Both the inclusion and the omission of "S" relationships may call on the student to reflect some more on the deeper meaning of certain principles and their influence on practice. A "C" relationship, if included, demands particular attention in the comments supplied to the student, including examples of possible erroneous chains of reasoning that (it at least appears to the author of the tutorial) the particular student is in danger of adopting. Quite complex interactions between concepts and principles may be explored with skillful use of the discussion guide. For example, if a student includes two mutually exclusive or conflicting statements, this inconsistency can be analyzed and its probable causes identified.

There are, of course, no theoretical limits on the use of the relationship matrix. However, practical considerations define quite finite limits which can handle some 90% of all discussions that normally occur in a given domain. In our case, we have limited our domain to 10 DECISIONS, (defined by the original interactive video simulation) and 20 GENERAL PRINCIPLES (those that the various experts we used tended to agree on). Whereas this matrix represents but a fraction of the cognitive structure that an expert manager may possess, it does seem to represent a reasonable model of that part that expert managers typically bring to bear on decision making tasks of the type simulated in DECISION POINT.

Finally, a reading of the last (so-called "default") comment illustrated in Figure 2, shows that a student may go beyond the structure imposed on the tutorial by our experts' viewpoints. We can invite a student who has included response items rated by the authors as irrelevant to attempt to justify his or her position by approaching the authors (or some live tutor) directly. Such impromptu live tutoring may serve not only to clarify/enrich the student's, but also the author/tutor's cognitive structure and may indeed result in restructuring and enriching the basic tutorial package. Such continuing interaction between students and experts/authors is probably essential in any instructional system that pursues the achievement of higher order cognitive objectives. Either the package is capable of learning from the student (the ultimate but as yet practically unattainable aim of intelligent tutoring system research), or the package should

always be implemented as an interface between students and expert/author. Continuing research is following up how to achieve this aim in computer-based interactive instructional systems.

3.0 ROLE OF THE COMPUTER IN STRUCTURAL COMMUNICATION

3.1 THE COMPUTER-BASED VERSION OF THE DEBRIEFING TUTORIAL

The problem with a print based version of this methodology is that given a list of 20 or more responses on the response matrix, the combinations of essential, supporting, or conflicting response may run into many thousands. Perhaps many of these are totally irrelevant combinations and therefore not likely to occur. Nevertheless, many alternative responses, not necessarily right or wrong, but worthy of one or other comment will appear. In addition, it can be cumbersome to select the appropriate discussion comments to read.

Given current advances in technology and advances in software, it is possible to convert the print based version of this methodology into a computerized version using an expert system-like program. We are currently experimenting with a software version of the DECISION POINT debriefing tutorial.

The shell for entering the structural communication debriefing tutorial was developed by IntelliSys, Inc using Microsoft C compiler. The shell was programed within ANSI standards to allow for total portability. The system allows for a person to input their own problem set (questions), response matrix (elements), discussion guide (actions), and discussion comments (response codes). The questions are entered with a number pointer and then text can be entered in free form within quotes. The same procedure is used to enter the elements and actions.

Response codes are entered to direct the program to deliver feedback specific to the student's answer. The response code of

$$2 = \{2,4,\tilde{}6\}$$

means to show feedback action 2 if the student included 2 and 4, but omitted 6 from his or her answer. In this response the commas are read as AND and the ~ symbol is read as NOT. The program does this by first checking if 2 is found in the student's answer; if it is, the answer is checked for 4, and if the number 4 is found the students's is checked for no inclusion of 6. This check is independent of the order in which the student has typed in his or her responses. If at any point in

the check, the program fails to find a match, the program moves on to check the next response.

The one disadvantage of this present system is the programmer must insert all combinations that need to be checked. Future development will add a feature that simplifies the authoring task. It will include code that will require the entering of fewer strings of possible combinations than is currently necessary. For a few items, the current authoring tool is not much of a problem. However, as response codes become more complex, the number of needed entries increases to unwieldy numbers. The added feature proposed by IntelliSis will help to increase the ease with which the system can be used.

However, the shell in its present form can handle any logic-statement composed of a combination of AND/OR/NOT gates, allowing quite ambitious analyses of the interrelationships among concepts that exist in the student's mind.

3.2 PRELIMINARY RESULTS USING THE DEBRIEFING TUTORIAL

The latest version of the debriefing tutorial was developed as an on-line CBI tutorial by Wende Pusch, using the shell we have just described (Romiszowski, Grabowski and Pusch, 1988). This version is still undergoing formative evaluation and is yet to be released for full scale experimental use. However, a number of real or potential problems have been encountered with the CBI version.

(a) The "holist" presentation of the response-components matrix.

As each response-component is typically a short phrase or sentence, it is difficult to get all 20 or 30 of these components on-screen at any one time. The current version of our software presents the components as a numbered list of sentences and students have to scroll up and down this list in order to make their selections. This they find to be less convenient than the previous tabular presentation of all the components on one sheet of paper. Also, an artificial linearity and sequence are imposed on the response-components, rather than the "holist" structure that is implied by the "response matrix".

There are several possible solutions to this problem:

- using much smaller print size on a high-resolution screen in order to get the whole "matrix" on-screen at one time;

- organizing the response components in a spreadsheet format that may preserve the structural, "holist", presentation, whatever the size of the matrix, but would allow two-dimensional scrolling, or windowing techniques to study items in detail while maintaining the overall structure in view;

- use of high quality graphics on a videodisc, possibly with touch-screen capability, to enable the selection of response components simply by pointing;

- maintenance of the response-matrix off-line, as a printed reference chart.

This last suggestion is not all that absurd, given that one response matrix may be used as the basis for a whole set of investigative problems (in our example case we have one matrix for ten problems that take an hour or more to work through). The matrix is constantly being referred to. The student may wish to have both problem-statement and response-matrix available at one and the same time. A lot of flipping back and forth between screens is avoided if two simultaneous displays are used - and why should not one of these be a printed chart?

It is interesting, in this context, to recall that way back in the early 1970's, when Structural Communication was being developed in the United Kingdom, a special input device was invented that allowed direct input of student responses to the computer from a printed response matrix. The paper chart was placed on a special touch-sensitive pad and the student responded by touching the response components. This student input was fed directly to a mainframe that performed the logical analysis of the response-pattern and presented the relevant comments to the student on a terminal screen. Perhaps the most appropriate way to enhance our current microcomputer-based version of structural communication, is to search for more appropriate interface configurations. Is it not paradoxical that current cutting-edge research and development efforts in the area of CBI interface design are focussing on more "natural" communication modes (meaning natural language communication and speech), when the bulk of non-computer-based research on communication and instruction suggests that in higher-order learning of complex and abstract content, speech is the least effective communication mode, written text is somewhat better, but special symbolic codes that imply the structure of the topic being communicated are best (e.g. see the research by Godycki and Romiszowski, 1970, on the teaching of theory in physics). What we require in higher education are better methods for communicating the structure of complex subject matter, rather than voice synthesizers and

language parsers.

(b) The recall of the context.

A second problem we have observed with our CBI version is that many students have difficulty, at the debriefing stage, in recalling exactly what happened during the interactive video simulation-game, what were the alternatives for each decision, what they, in fact, decided and why they made the decision they did. In the earlier, paper-based, version of the tutorial, we had attempted to minimize this problem by creating a "Manager's Diary" - a sort of log-book containing the ten decision points, the alternative options, any reference material provided in the original videodisc and planned spaces for the students to note the decisions made and the underlying reasons. During the debriefing tutorial, students were encouraged to refer back to their "diary" to remind themselves of the details of each decision point. Students completed (and benefitted from) the "Manager's Diary" because we, the experimenters, insisted that they fill in the blanks and hand it in. But in general, they tended to resent the extra task that intruded into the free flow of the interactive simulation-game.

In our current CBI version of the tutorial, we have therefore abandoned the use of the "diary". This has caused the reappearance of the "recall of the context" problem that had initially motivated us to supplement the interactive videodisc with a paper-based "diary". Wende Pusch has attempted a different strategy, which involves the replacement of the rather short and to-the-point questions, by much longer texts that review the situational context in which the problem question is embedded. This has been relatively successful in overcoming the problems that some students have demonstrated with recall of the relevant details of the videodisc scenarios. On the other hand, these "long" versions of the problem questions take up a lot more space on the screen, require more reading time from all students and make the tutorial appear to be excessively verbal and may cue responses that they may not have thougth about otherwise.

Once again, there are several possible approaches to solving these new problems:

- make the contextual information optional, so that students may call it up only in cases where the short direct formulation of the question proves to be unclear or insufficient;

- in an integrated package, where the debriefing tutorial is also on the videodisc, the recall of the context could be

achieved more realistically and less verbally by means of "flashbacks" to parts of the simulation-game's scenarios;

- rather than play a two-hour game and only then engage in another hour or two of in-depth reflection on all ten of the topics covered by the game, it is possible to offer the reflective tutorial as ten separate on-line "help" sequences, available to the student during the game itself, at the point-of-decision.

This last suggestion opens up a whole new "can of worms" as the whole basis of the instructional design of the interactive video simulation would then be modified. Several important research questions spring to mind. Would the resulting package still be an experiential learning exercise, or will it have reverted to a case-study-based form of tutorial CBI? Would this reduce the very high level of motivation to participate, that the current interactive video simulation-game generates? How could such integrated "invitations to reflect" be most naturally built into the storyboard of the simulation-game? Should they be abstract moments of reflection, or built-in dramatizations of reflective discussions between the student and the other characters on the videodisc, or should there be a simulated tutor figure with which the learner can converse?

Other problems being encountered with our current CBI version of structural communication are related to programming "bugs" and inefficiencies, which, at least in theory, are easily corrected and have no great instructional design/development implications. The two problem areas outlined above, however, are "bristling" with research questions that we are planning to investigate in the continuation of our work.

4.0. CURRENT AND FUTURE RESEARCH

4.1. STRUCTURAL COMMUNICATION AS "COMMUNICATION BY MEANS OF STRUCTURE"

Anthony Hodgson and his research collaborators coined the term "structural communication" in the late 1960's to describe their particular approach to the design of educational communications that transmit the "deep structure" of one person's viewpoints on a topic, to another. There have, however, been many other attempts. These include:

- various methodologies of concept-mapping, such as "Pattern Notes" (Fields, 1984);

- various methods of flowcharting and diagramming procedures

and processes (algorithms, decision tables, when/if charts, if/then charts - see Horn 1976 for a review of many of these);

- various approaches to the visual representation of structure and content, such as hierarchical taxonomic tree-diagrams (e.g. hierarchical analysis of instructional objectives as proposed by Gagne 1965, 1974), two, three (or "n") dimensional matrices and classification schemata (e.g. the "Managerial Grid" of Blake and Mouton 1968), the two-dimensional matrix tabulation used to communicate the essentials of Component Display Theory by Merrill 1983, the three dimensional model of the human intellect used by Guildford 1967, the multi-dimensional schemata used in personality inventories and profiles, or in the Repertory Grid technique of representing personal constructs, used by Kelly 1955);

- various methods of diagrammatically describing complex structure and relationships, such as Venn Diagrams used to explain mathematical laws and relationships, modified Venn Diagram techniques used to explain the structure of certain complex theories in physics and the sciences (Godycki, 1968, Godycki and Romiszowski 1970), the use of circular and other relationship diagrams to communicate groups of interrelated concepts and principles in a structured manner (Romiszowski 1981), networks, semantic nets and "entailment meshes" (e.g. Pask 1976, Burton 1982, Payne 1988), systems diagrams of many forms, used by too many writers to mention, to communicate the structure and interaction of systems and sub-systems, both concrete and conceptual.

This rich variety of approaches, illustrates the basic importance of the problem of communicating the deep structure of knowledge, an importance which is growing exponentially at present due to the commercial promise of expert systems and the associated needs for more effective and efficient methods of knowledge elicitation and representation. Most of the approaches have, however, restricted themselves to the uni-directional communication of a structure "owned" by an "expert" to others who have less expertise in the given domain. Few have concerned themselves with the sharing of structures between two or more partners in a conversation. And yet, many theorists and philosophers (back to Plato's Republic and beyond) have maintained that a principal aim of education (particularly higher education), is such sharing and mutual enrichment of viewpoints, cognitive structures, schemata, call them what you will. Many practicing teachers attempt to do this in their face-to-face teaching. But in CBI, there have been few attempts to achieve

this. The early Plato systems made some efforts in this direction, but with the advent of stand-alone microcomputers, much of the impetus was lost. Pask's Conversation Theory and its embodiment in the CASTE system of conversational tutorials (Pask & Scott 1973) was a theoretically more ambitious attempt which has not however resulted in many practical working systems (perhaps due to its theoretical sophistication). The Structural Communication approach, although not very extensively used so far, has a proven track record of success in projects where it has been used (see Egan 1976, Hodgson & Dill 1970, Romiszowski 1976). It is an approach based on a relatively simple methodology, yet based on a highly sophisticated theory of the learning-teaching process. As the current study shows, it can be quite readily automated for delivery by today's microcomputers, using the computer in the appropriate role of complex analysis of complex student responses, and not just as a glorified page-turning device. Furthermore, the methodology as developed by Hodgson and his associates, is capable of further refinement and sophistication, by drawing on some of the other areas of research and development on the communication of cognitive structures, which we have just reviewed. One thrust of our ongoing research is to explore the possibilities of further refining and enhancing the Structural Communication methodology, in order to transform it into a powerful and flexible courseware design and authoring system, appropriate for higher-order conceptual learning tasks.

Another research direction associated with the development of structural communication, is the design of CBI interfaces that effectively communicate the structure of an idea, both from the courseware to the student and vice versa. The currently used "response matrix" is just one possible mode of such two-way communication of structure. Interactive screen displays, as already used extensively in CAD/CAM systems provide us with other alternatives. Several researchers are working on the visual display, on screen, of the structure of a domain of knowledge under study, in a dynamic, interactive manner, sensitive to the changes of structure proposed by both "tutor" and "student" (a distinction that may progressively become more blurred). One interesting approach to this problem is the work of Kommers (1988) on "Textnet" a Hypertext-type shell which in addition to accepting and storing information as a network of interconnected nodes, presents to the user a visual map of the structure of the stored knowledge-base and its own (computed) weightings of the relative importance of each node in the knowledge structure. This machine-view of the importance of the knowledge stored is interactive, in that the user may specify different criteria by which importance is to be assessed, may override or change the relative importance of items by changing the interconnections between key items in the knowledge base, may zoom in or out to

examine the structure in more detail or to get a more global view, etc. Such current developments in both the hardware and the software of interactive computer interfaces, open up many new avenues for the design of CBI systems that will assist students not only to "think" in a reflective manner about the causes and implications of the phenomena they experience, but also to "reflect", in a yet deeper sense, on the structure, the validity and the practical utility of the conceptual schemata they are developing in their own heads. We believe that our work on structural communication will enable us to reach these goals.

4.2. STRUCTURAL COMMUNICATION AS AN INTERFACE BETWEEN STUDENT AND TUTOR

As developed and implemented by Anthony Hodgson, Structural Communication is a relatively "shallow" analysis of a student's understanding of a topic, in the sense that the questioning of the student descends to only one level of possible difficulties or misconceptions. Each problem on the topic of study explores a different (though possibly related) facet of the topic. The student response reveals the conceptual structure that the student has formed in relation to this specific problem. The author/tutor, from his/her own expertise and teaching experience, formulates the response analysis and discussion guide, attempting to predict all possible/probable misconceptions and their root causes, alternative viewpoints and their relevance or validity, etc. The specific comments are then written to address all the predicted variety of response in a manner that will cause the students to reflect and rethink their viewpoints or clear up their misconceptions. This is easier said than done, especially in one step or "level of analysis". Often in face-to-face teaching, in order to be at all certain of one's diagnosis of the reasons behind a particular student response or viewpoint, one is led to ask some subsidiary diagnostic questions, descending two, three or more levels of depth of analysis. Current simple implementations of structural communication do not descend to such depths of subsidiary analysis. Indeed, in a paper-text-based implementation, the problem for the student of keeping track of all relevant comments for a set of five or six independent problem questions, related directly to the domain or topic of study, is already quite taxing. Imagine the problems of keeping track if each of the initial problem questions were to lead to one or more subsidiary "level two" questions and some of these were then to trigger off yet further "level three" questions, and so on. Inevitably, some of the lower level questions would interact with more than one of the initial problems, so that quite a complex network of diagnoses and decisions would have to be tracked. The task may well be quite beyond the student's own capabilities. However, the tracking of

such a complex network is quite a simple task for a computer. The automation of the basic structural communication methodology, is but the first step towards the chaining of a series of such exercises, descending to a requisite level of analysis, that will enable a much more thorough and confident diagnosis to be performed, leading to much more specific and helpful feedback comments.

The resulting network of questions and related comments will not be entirely hierarchical, due to interactions between questions and sub-questions. The resulting network of screens will be non-linear and may well resemble a hypertext document, with multiple paths by which one can progress from one node to another. However, unlike the typical hypertext documents, which relate one screen to another by means of keywords, or "buttons", and are more or less totally under user control, a multi-level structural communication would allow user browsing up to a point, but would automatically present certain comment screens, under system control, when the diagnosis process identifies a particular student need or a viewpoint that can be challenged. We hope to implement such a system by combining the Structural Communication software we are developing with hypertext-like shell for storing the questions and comments.

A related research area concerns the ways in which such a tutorial system can best be stored and delivered. Our current work sprang out of research and development of interactive videodiscs. This is a medium that appears ideally suited to the storing of large tutorial knowledge bases of the type we are describing, allowing in addition the presentation of various modes of information, from text to video. There is one limitation of current videodisc technology which may be of some importance to the results of our research. As mentioned earlier, we think it essential, in subject areas that are best suited to exploit structural communication (complex, conceptual topics in which it is possible to defend several alternative viewpoints), that there is provision for dealing with the occasional unpredicted viewpoint that is nevertheless ably defended by the person who suggests it. Often, such new slants on the topic, merit being included in the package for analysis by future students. The permanent and initially expensive nature of current optical videodiscs, discourages the regular review or updating of the tutorial. However, current developments in digital video and WORM technology may well remove this limitation. We look forward to the development of systems that will allow us to store and present easily updatable interactive, questions-driven, hypermedia. The structural communication methodologies we are developing will enable us to design such interactive instructional systems that will take full advantage

of the emerging presentation technologies, in the pursuit of higher order cognitive learning.

Finally, we are addressing the design of interactive distance education systems for higher order learning. In such a system, the structural communication package takes the role of a highly interactive textbook, that may be stored locally on a videodisc or CD, or alternatively may be downloaded from a remote central computer. Whichever of these configurations is adopted, there is provision to upload, from each student to a remote "author/tutor", any student comments or queries which are not automatically dealt with by the package. Thus, the comment in the last "default" cell of Figure 2, which invites the student who thinks there are genuine reasons for the inclusion of one or other of the response components that the author deems irrelevant, to "let us know your opinions", is for real. These minority opinions will be uploaded from the student to the author/tutors and will, in due course, get a personal reply (perhaps by E-mail). Similarly, the response-matrix in Figure 1 (or any other alternative response device) may have a standard "open" cell, which allows students to add further, unpredicted response components, in their own words, to be uploaded to the author/tutors for consideration and personal comment. When deemed appropriate, the authors can decide to modify the tutorial package to incorporate any interesting original viewpoints expressed by students. Current research plans include the simulated implementation of such an interactive distance education system, in which a structural communication package acts as an interface between a group of students and a "distant tutor".

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DECISION POINT - Response Matrix

1 For any given policy the aim is to maximize profit margin	2 Sales staff must have sufficient incentives to sell	3 Numbers in monthly reports are an important guide in policy and decision-making	4 A long& complicated decision-making process will slow down the sales process resulting in reduced sales
5 Sales staff should be given greater authority so that they can close a sale once they spot an opport--unity	6 It is important that the appropriate level receive the inform--ation necessary to perform effectively	7 To effectively sell a complex product, sales staff should know all the technical details of it	8 Volume of sales must be related to the production capacity of the factory
9 Regular performance appraisal of personnel and feedback of results leads to improvement and maintenance of standards	10 Changes in job classification should be based on perfor-mance and demon-strated skills	11 Personnel who 'have been around' several years have a wealth of experience and their services are invaluable to the firm	12 Managers and sub-ordinates must learn to identify tasks that are critical to success on the job and concentrate their time & attention on these tasks
13 The efficient perfor-mance of one depart-ment should not be bought at the expense of the efficiency of another	14 Sales reflect market trends, therefore, extremes in policies i.e. too strict /too lenient cannot be imposed	15 A key competence of management is to be able to delegate responsibility to sub--ordinates	16 Increasing the number of sales staff will always result in increased sales
17 To ensure that selling is done efficiently, managers should be around to help sell	18 Regional managers should be part of corporate decision-making	19 Sales representatives should be selling, it is not appropriate for them to be techni-cal experts	20 Establishing sales quotas can be used as a standard to measure performance against - hence it is one part of of an overall performance appraisal system

FIGURE 1

THE TUTORIAL BACKUP OF THIS DECISION PONT

The problem question asked is "which of the principles on the response matrix do you think lend support to the correct decision on solving the technical support problem?" Analysis by experts and student input during development led to the following "Program" (only an outline of actual responses is show here).

If the student--	Then present the following comments
Omitted 13 and 19 Considered essential	Recall events in the simulation that show the disruption caused by "borrowing" product engineers AND the sales losses when salesman get too involved in non-sales related tasks.
Omitted 4 and/or 11 Considered Subsidiary	Discuss possible solutions that would help to speed up the sales processes, use the experience of existing technical staff, but will NOT disrupt the work of other departments.
Included 7	Allow that some technical knowledge is helpful to effective ssales, but point out that in the high-tech environment in which most sales are carried out, in this particular company, nothing short of fully qualified engineers is OCCASSIONALLY called for. But can we affortdengineers as salespeople?
Included 16	Allow that having engineering support for technical problems increases the amount of time thaesalesmen spend on direct selling. This is like increasing the sales force, but in fact, AVOIDS the numerical increases in the number of sales staff, that may have all sorts of detrimental effects on profits.
INCLUDED 2 or more of (1,2,3,5,6,8,9,10,12,14,15 17,18,20.)44	Point out that most of these principles appearslargely irrelevant to the specific problems under discusion. Some are of marginal relevance due to their blanket generality, but you should have more specific reasons for quoting them. Others may appear to you of great significance for reasons that have so far eluded us. If you think this is so, let us know your opinions.

Figure 2

Element	Managerial Effectiveness	Commission Policy	Promotion of Harriet Dorfman	Sales Support Workflow	Increase in Sales Staff	Report Distribution	Credit Policy	Discount Approval Policy	Technical Support	Sales Quotas
1 = Managers must be able to delegate responsibility to subordinates.	E		E					E		
2 = Training of personnel is necessary to help increase their effectiveness.			E							
3 = Policies that are either too strict or too lenient may have a negative effect on sales.		S					E	E		E
4 = Increasing the number of personnel should lead do increased departmental productivity.				C	C					
5 = Changes in job classification should be based on performance and demonstrated skills.			E							
6 = Setting sales quotas will take the edge off selling, money is the only incentive the reps need to increase sales.										C
7 = Increasing the staff does not necessarily increase productivity.				E	E					
8 = Sales staff must have sufficient incentive to sell.		E			S			S		E
9 = Long and complicated processes within the company may bog down the sales process.				E			S	E	S	
10 = Personnel must be able to identify tasks that are critical to success and concentrate their time and attention on these tasks.	E		E		E					
11 = The available reports do not contain any information that would be useful to sales rep.						C				

Figure 3 (Page 1)

Element	Managerial Effectiveness	Commission Policy	Promotion of Harriet Dorfman	Sales Support Workflow	Increase in Sales Staff	Report Distribution	Credit Policy	Discount Approval Policy	Technical Support	Sales Quotas
12 = The aim of any policy is to maximize the profit margin.		E					E	E		
13 = Sales volume should be related to available stock and production capacity		S								E
14 = Information contained in reports must be distributed to persons most capable of using them.					S					
15 = An established performance criteria can be used as a standard to measure performance and be part of the appraisal system.										E
16 = The sales staff should be well versed in the technical details of the product line so they can better serve the customers.									C	
17 = Managers should closely monitor staff to ensure that they are performing up to standards.	C		C							
18 = Sales reps do not have a sufficient technical background and may be better served by being provided with back-up technical expertise than technical training.									E	
19 = Reports often contain information that could be useful to sales reps and regional managers.						E				
20 = The decision making process should include managers at all levels within a department.										E

Figure 3 (Page 2)

Element	Managerial Effectiveness	Commission Policy	Promotion of Harriet Dorfman	Sales Support Workflow	Increase in Sales Staff	Report Distribution	Credit Policy	Discount Approval Policy	Technical Support	Sales Quotas
21 = Regular performance appraisals of personnel, with feedback of results, leads to improvement and maintenance of standards.			E			S				E
22 = Personnel who have been with the company for many years have a wealth of experience that make their services invaluable to the company.			C							
23 = It is important to identify redundancies in administrative procedures so they can be corrected.				E						
24 = Staff are promoted to managerial positions based on past performance on the job, but often need training in order to develop managerial skills.	E		E							

Figure 3 (Page 3)